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Original Article

Atrial synchronous left ventricular only pacing with VDD pacemaker system – A cost effective alternative to conventional cardiac resynchronization therapy

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ABSTRACT

Introduction: Atrial synchronous left ventricular (LV) only pacing using two leads and VDD pacemaker could be a cost effective alternative to conventional cardiac resynchronization therapy (CRT).

Methods: We implanted right atrial (RA) and LV leads with VDD pulse generator (LV only pacing) in five carefully screened heart failure patients who could not afford conventional CRT. All had NYHA class III/IV symptoms despite maximal guideline directed medical therapy. The sensed atrioventricular delay was programmed to pre-excite the LV and achieve fusion beat. Response to treatment was assessed at 6 months.

Results: Four patients were males. The mean age was 58 ± 12 years. At follow up, there was improvement in electrocardiographic, and echocardiographic parameters: Mean QRS duration decreased from 174 ± 17 msec to 128 ± 10.9 msec ($p = 0.009$), LV end-diastolic diameter decreased from 73.2 ± 12 mm to 65.8 ± 9.6 mm ($p = 0.026$), LV end-systolic diameter decreased from 65 ± 12 mm to 54 ± 10 mm ($p = 0.020$). There was a trend towards reduction of LV end-systolic and end-diastolic volumes. LV ejection fraction improved from 25 ± 6% to 34 ± 6% ($p = 0.013$) and left atrial dimension reduced from 44 ± 4 mm to 39 ± 5 mm ($p = 0.045$). All patients improved clinically.

Conclusion: RA-LV pacing using VDD pacemaker is a safe and effective technique of CRT. This may be a cost effective alternative to conventional CRT for patients in developing countries.

Abbreviations: BiV, Biventricular pacing; CRT, Cardiac resynchronization therapy; GDMT, guideline directed medical therapy.

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1. Introduction

Cardiac resynchronization therapy (CRT) with biventricular (BiV) pacing has emerged as an important treatment option in patients with heart failure refractory to guideline directed medical therapy (GDMT).[1] Though found to be very effective in such patients, CRT is underutilized in a developing country like India, due to its high cost. There is no device database/registry in India from where data about CRT usage in the country could be derived. In our centre, only about one fifth of heart failure patients with class I indication undergo CRT implantation (unpublished data).

Univentricular pacing i.e., pacing the right atrium and left ventricle (LV only pacing) instead of both right and left ventricles has been explored as an alternate treatment modality to achieve CRT in many studies.[2–11] LV only pacing has emerged on the knowledge that restoration of intraventricular dysynchrony is sufficient to restore LV synchrony. This argument makes RV lead pacement redundant in certain conditions of heart failure.[7,8,12] Trials evaluating LV only pacing used CRT pacemaker system. These studies postulated that LV only pacing can be offered to patients at a substantially reduced cost compared to BiV pacing.[3,13] We offered LV only pacing using VDD pacemaker system to patients who could not afford conventional BiV pacing. We report here our experience in using VDD pacemaker system for CRT.

2. Methods

This is a retrospective analysis of patients in whom CRT was performed using VDD pulse generator which senses RA and paces only LV. We offered this treatment to patients who had symptoms of heart failure despite GDMT and could not afford conventional CRT. The procedure was performed on patients who had the following: NYHA functional class III or ambulatory class IV, sinus rhythm, LBBB, QRS duration of $\geq$150 ms, LVEF $\leq$35%, left ventricular end-diastolic diameter (LVEDD) $\geq$55 mm and on continuous GDMT for at least three months prior to procedure. We excluded patients who had sinus bradycardia, atrial fibrillation, atrioventricular conduction disease and renal failure (serum creatinine >1.5 mg/dl). Patients with hypertrophic or restrictive cardiomyopathy, suspected acute myocarditis, valvular heart disease, acute coronary syndrome and those who underwent coronary revascularization in the past three months were not considered for the procedure.

2.1. Pacemaker implantation and programming

We used standard VDD pacemakers to synchronize RA and LV. The RA and LV leads were positioned transvenously through the left subclavian vein using an extrathoracic approach. A coronary sinus venogram in levophase was obtained prior to LV lead placement. The LV lead was positioned according to standard protocol avoiding the great and middle cardiac veins. We preferred the lateral wall for LV lead placement, where the local ventricular activation was at the terminal portion of the QRS (latest site of LV depolarisation). The sensed AV delay was programmed to pre-excite LV and allow the native conduction to depolarize RV. The programmed AV delay and LV lead thresholds for individual patients are given in Table 1. Patients were discharged between 3 and 5 days after the implantation with an advice to follow strict medical therapy for heart failure.

2.2. Follow up

Patients were periodically followed up in the device clinic. Response to therapy was assessed six months post implantation using clinical and echocardiographic parameters: NYHA functional class, LV dimensions and volumes, ejection fraction (EF), LA dimension and mitral regurgitation (MR) jet area.

2.3. Echocardiographic methods

M-mode measurements of the two-dimensional parasternal long axis view was used for assessment of LV dimensions. LV volumes and LVEF were calculated using Simpson's biplane method. LA dimension was measured in parasternal long axis view and MR jet area by vena contracta method.

3. Results

A total of seven patients underwent CRT with LV only pacing between October 2009 and January 2013. Two patients had their follow up assessments done elsewhere. Hence, results of only five patients are shown. The mean age of five patients was 58 ± 12 years. Four were males. Four were in ambulatory

Table 1 – Clinical, echocardiographic and pacing parameters of individual patients at baseline.

S. no	Age in years	Sex	NYHA functional class	QRSd (msec)	LVEDD (mm)	LVESD (mm)	LVEDV (ml)	LVESV (ml)	LAd (mm)	MR jet area (cm2)	Pacing parameters	
											AV delay (msec)	LV lead threshold (volts)
1	68	F	IV	180	70	67	323	254	42	4.8	120	1.5
2	40	M	IV	170	73	64	166	126	47	14.6	140	1.0
3	68	M	III	160	73	66	165	110	40	2.1	160	1.5
4	62	M	IV	160	92	81	390	310	44	15.7	120	2
5	54	M	IV	200	58	47	193	115	49	1.1	140	1.5

LVEDD indicates left ventricular end-diastolic diameter; LVESD, left ventricular end-systolic diameter; LVEDV, left ventricular end-diastolic volume; LVESV, left ventricular end-systolic volume; EF, ejection fraction; LAd, left atrial diameter; MR, mitral regurgitation.

functional class IV and one in class III. Four patients had dilated cardiomyopathy and one, ischaemic cardiomyopathy. Baseline characteristics and pacing parameters of individual patients are shown in Table 1.

3.1. *Response to LV only pacing*

All patients had an improvement in clinical status as assessed by NYHA functional class. There was good improvement in all end points assessed (Table 2) with significant improvement seen in QRSd, LV dimensions and EF (Fig. 1). Diuretic requirement reduced substantially in all patients. Device interrogation did not show any atrial or ventricular arrhythmia. There was no mortality.

4. Discussion

To the best of our knowledge, this is the first time a VDD pacemaker system has been used for cardiac resynchronization. This method was beneficial in significantly reducing the costs for the patients and also providing clinical improvement. The LV pacing used in this series of five patients resulted in LV reverse remodelling thereby improving the clinical status of all patients.

The safety and efficacy of LV only pacing have been explored in several studies[6,8,9,11,14–18] and found to be comparable with the time tested BiV pacing.

4.1. *Haemodynamic effects*

Both LV only and BiV pacing have demonstrated similar hemodynamic results during acute studies with favourable changes in pulmonary artery pressures, cardiac output, systemic blood pressure and dp/dt.[6,14,15] Comparable benefits between LV only pacing and BiV pacing have been demonstrated in mid-term[8,9] and long-term studies as well.[16] In a study by Auricchio et al,[17] three months of active LV pacing was compared to three months of inactive pacing in patients with severe congestive heart failure and wide QRS duration. During active LV pacing, there was a significant increase in peak VO2 and in 6 min walk distance. Patients with QRS duration >150 ms had more pronounced benefit than with a lesser QRS duration.

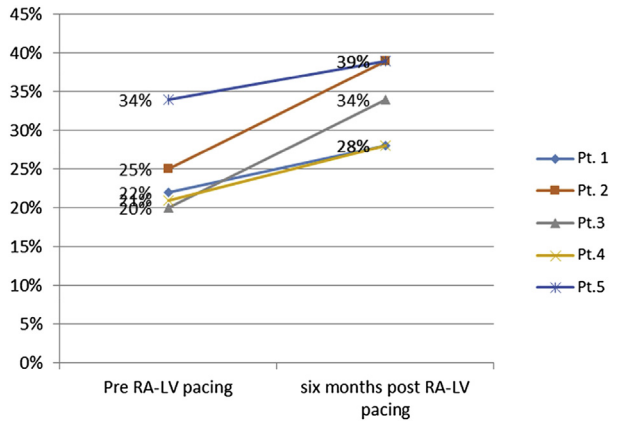

Fig. 1 – Change in left ventricular ejection fraction in individual patients six months post RA-LV only pacing. The figure shows change in left ventricular ejection fraction as assessed by echocardiography in all five patients who underwent RA-LV only pacing from baseline to six months following procedure.

Table 2 – Comparison of the mean effect of CRT with RA-LV only pacing on *electrographic* and echocardiographic parameters in all patients.

Variables	Pre-procedure (mean ± SD)	Six months post procedure (mean ± SD)	*p*-value (CI 95%)
QRSd (msec)	174 ± 16.7	128 ± 10.9	0.009
LVESD (mm)	65 ± 12.1	53.8 ± 9.8	0.026
LVEDD (mm)	73.2 ± 12.2	65.8 ± 9.6	0.020
ESV (ml)	183 ± 92.6	152.6 ± 72.9	0.103
EDV (ml)	247.4 ± 102	242.8 ± 117	0.862
LVEF (%)	24.6 ± 6.1	33.6 ± 5.5	0.013
LA dimension (mm)	44.4 ± 3.6	38.8 ± 5.02	0.045
MR jet area (cm^2)	7.6 ± 5.9	2.2 ± 1.7	0.076

LVEDD indicates left ventricular end-diastolic diameter; LVESD, left ventricular end-systolic diameter; ESV, End-systolic volume; EDV, Left ventricular end-diastolic volume; LVEF, Left ventricular ejection fraction; LA, left atrium; MR, mitral regurgitation. *p* value <0.05 was considered statistically significant.

4.2. *Clinical benefits*

LV only pacing showed similar improvement to BIV in terms of functional class, quality of life score and exercise tolerance as observed in a study with a cross-over design by Auricchio et al.[18] The study compared two active periods of four weeks each of LV only and BIV pacing. In a follow up study (12 months) with exclusive LV only pacing by Blanc et al[19] in severe congestive heart failure, sinus rhythm and LBBB, there was significant improvement in NYHA functional class, exercise tolerance and blood levels of norepinephrine. In our patients of CRT with LV pacing using VDD pulse generator, there was improvement in clinical and echocardiographic parameters in all the five patients.

GREATER EARTH,[11] a double-blind, cross-over study showed similar benefits between LV only pacing to BiV in terms of exercise capacity, LV function and volume, and circulating levels of N-terminal natriuretic peptide. In this study, among the clinical non-responders to BiV, 21% improved and among the non-responders as assessed by echocardiography, 17% responded favourably when crossed over to LV only pacing.

Though many studies have demonstrated the non-inferiority of LV only pacing to BiV, the acceptance of this mode of pacing therapy in clinical practice is very low. From a clinical perspective, the 2013 ESC guidelines on pacing[20] recommends LV only pacing in non-pacemaker dependent patients "to decrease the cost and complexity of the procedure

Table 3 – Comparative assessment of cost involvement between atrial synchronized biventricular cardiac resynchronization therapy and VDD pacemaker.

	BiV CRT system	CRT using VDD pacemaker system
Device with lead system	Rs. 347,000	Rs. 175,000
Procedure	Rs. 80,000	Rs. 30,000
Hospitalization	Rs. 30,000	Rs. 15,000
Total cost	Rs. 457,000	Rs. 220,000

The cost mentioned in the table is the approximate cost offered to patients in our institution.

and increase the longevity of the device". As placement of LV lead compared to RV consumes more time and needs more expertise, the benefits from reducing time or technical complexity may not be significant by employing LV only pacing but, there is definitely a significant cost benefit involved.

4.3. *Cost effectiveness*

In our series, all five patients were in advanced heart failure with NYHA class III-IV symptoms and re-modelled LV despite GDMT. They would have continued to deteriorate if CRT was not offered to them. Hence, we offered CRT using VDD pacemaker system. Employing LV only pacing using VDD pulse generator system has definite cost benefit over BiV (Table 3).

This form of resynchronization will be useful in patients with good AV nodal conduction and who are unlikely to develop an AV block in future. Patients having sinus node dysfunction with indication for atrial pacing and those who require a concomitant intracardiac defibrillator are not ideal candidates for LV only pacing.

4.4. *Limitations*

Ours is a non-randomized study with no control arm. In addition, the procedure was offered on compassionate grounds to a selected subset of patients with advanced heart failure. Our inclusion criteria were stringent and included patients who were most likely to benefit from BiV as seen in many randomized studies. This might explain the high responder rate observed in our patients. Therefore, the applicability of LV only pacing in other conditions could not be commented based on our experience. Further long-term follow up studies are needed to identify the suitable population that might achieve maximum benefit from LV pacing using VDD pacing system.

5. Conclusion

RA-LV pacing using VDD pacemaker is a safe and effective technique of CRT. This may be a cost effective alternative to conventional CRT for patients in developing countries. Large randomized studies are needed to confirm our observations.

Conflicts of interest

All authors have none to declare.

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